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Line of Sight-Forward (Heavy) Surrogate Assessment

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The U.S. Army Air Defense Artillery School (USAADASCH) briefed the Forward Area Air Defense (FAAD) Line of Sight-Forward (Heavy) (LOS-F-H) concept at a mid-July 1986 Army Systems Acquisition Review Council meeting. The briefing called for a manpower and personnel integration (MANPRINT) assessment of the operability and supportability of the LOS-F(H)'s gun-missile or "hybrid" system. USAADASCH asked the Army Research Institute to conduct the MANPRINT assessments, and the Human Engineering Laboratory to provide support in its areas of specialty. Based on Manpower, Personnel, and Training assessments of one prototype or "surrogate" system from two manufacturers, it was found that operability and support requirements could be met by the anticipated transition MOS, 16R. Human factors engineering, system safety, and health hazard evaluations, while identifying specific areas of noncompliance and risk, uncovered no features in the prototype systems that invalidate the feasibility of the hybrid concept. Specific suggestions were made to help guide the planned LOS-F(H) Candidate Evaluation.

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FOREWORD

The Fort Bliss Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) responds to research and development (R&D) needs of the U.S. Army Air Defense Artillery School (USAADASCH) in areas such as the manpower and personnel integration (MANPRINT) program. Of special interest to USAADASCH is the periodic quick-response requirement in which ARI may be of technical assistance. An Army Systems Acquisition Review Council (ASARC) study of the Forward Area Air Defense (FAAD) Line of Sight-Forward (Heavy) (LOS-F-H) component presented one such challenge. A major concern of that review was whether representative soldiers from the transition target audience could operate the LOS-F-H's gun-missile or "hybrid" system.

This report describes the effort and findings of the concept evaluation carried out by a task force from ARI, the USAADASCH Directorate of Combat Developments, and the Army Human Engineering Laboratory (HEL). Two manufacturers provided a prototype or "surrogate" system for use in this evaluation. The period from project initiation to ASARC was approximately 6 weeks.

The use of this report in the ASARC is evidence of the benefits of close and timely cooperation within Army agencies and with the contractor community. Further development of the MANPRINT concepts and research presented in this report will be pursued as the LOS-F-H and other FAAD systems progress through the procurement cycle, and will benefit the Army user community and military managers and the military R&D community.

ACKNOWLEDGMENTS

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LINE OF SIGHT-FORWARD (HEAVY) SURROGATE ASSESSMENT

EXECUTIVE SUMMARY

Requirements:

The U.S. Army Air Defense Artillery School (USAADASCH) briefed the Forward Area Air Defense (FAAD) Line of Sight-Forward (Heavy) (LOS-F-H) concept at a mid-July 1986 Army Systems Acquisition Review Council (ASARC) meeting. The briefing called for a manpower and personnel integration (MANPRINT) assessment of the operability and supportability of the LOS-F-H's gun-missile or "hybrid" concept.

In early June 1986, USAADASCH asked the Army Research Institute's Fort Bliss Field Unit to conduct an operability and supportability assessment. The Army Human Engineering Laboratory (HEL) was to provide human factors engineering, system safety, and health hazards evaluations. Four general questions were of interest: (1) What are the operator human factors concerns? (2) For the proposed operating environment, is the man-machine function allocation viable in such a hybrid system? (3) Are operator performance requirements reasonable? (4) What are the manpower, personnel, and training requirements, and can these be supported with anticipated resources?

Procedure:

The concept feasibility assessment was conducted using two manufacturers' prototype or "surrogate" weapon systems to provide baseline data for addressing MANPRINT issues. Operator workload ratings derived from several predecessor systems also provided a comparative baseline. A front-end analysis identified mission and performance requirements. The operability analysis then determined the performance role of the operator and associated health and safety concerns. The supportability analysis looked at manpower and personnel affordability from an organizational, staffing, and soldier quality perspective. The training requirements analysis was guided by the TRADOC systems approach to training.

Findings:

The analysis of the surrogate systems indicated that operator task workload is no greater than that associated with baseline predecessor systems and that representative soldiers from the current personnel pool can operate a hybrid-concept system.

Analyses indicated that the Army can support such a system with respect to quality of personnel and ability to train these personnel. Identified design deficiencies affecting human factors engineering, safety, and health hazards were generally judged correctable and not a factor in the feasibility of the hybrid system concept.

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INTRODUCTION

Background

The Line of Sight-Forward (Heavy) (LOS-F-H) element of the Forward Area Air Defense (FAAD) system was scheduled to undergo Army Systems Acquisition Review Council (ASARC) evaluation in mid-July 1986. As part of this review, manpower and personnel integration (MANPRINT) concerns (human factors engineering, system safety, health hazards, manpower, personnel and training) for the LOS-F-H and the Army's ability to support manpower, personnel and training (MPT) requirements were anticipated to emerge as major issues. Accordingly, the U.S. Army Air Defense Artillery School (USAADASCH) required that a preliminary MANPRINT assessment of the LOS-F-H concept be carried out as part of the preparations for the ASARC meeting.

The U.S. Army Research Institute (ARI), and the U.S. Army Human Engineering Laboratory (HEL) were requested by USAADASCH to conduct a MANPRINT assessment of two weapon systems which were (a) similar in concept to the proposed LOS-F-H and (b) currently available (in prototype form) from manufacturers. These two weapon systems were to be used as surrogates of the LOS-F-H concept and, as such, provide an exemplary baseline from which MANPRINT issues could be addressed.

LOS-F-H Operational Requirement

Employment

The LOS-F-H serves as part of the combined arms team by providing front-line air defense against attacks by high performance fixed- and rotary-wing aircraft, as well as self defense fire against ground targets. Because of its hardness, the LOS-F-H is to be capable of operating side-by-side with maneuver elements during all types of tactical operations. These maneuver forces operate in all types of terrain, weather, and climatic conditions to include reduced visibility while executing day/night operations to accomplish their assigned missions.

LOS-F-H will be integrated with U.S. Army High to Medium Altitude Air Defense (HIMAD) and U.S. Air Force fighter air defense assets through the FAAD Command, Control, and Intelligence (C^2I) system, which will pass target information and command and control messages within the integrated air defenses.

Threat

The threat to the maneuver force and critical assets against which LOS-F-H will defend in day/night operations, in a countermeasures environment, and under all weather conditions is composed of the following elements:

- Rotary-Wing (RW): Attack/Observation/Troop and Equipment Carrying Helicopters

- Fixed-Wing (FW): Close Air Support, Fighters, Fighter Bombers, Bombers, and Unmanned Aerial Vehicles (UAV)

- Ground Forces (GF): Wheeled Vehicles and Dismounted Troops

Although this study is focused on the LOS-F-H component of the FAAD system, it is important to recognize the interrelationship of this component with the rest of the FAAD assemblage. Figure 1 is an illustration of the air threat and the FAAD total system response to that threat. From near the Forward Line of Own Troops (FLOT), the combined arms, LOS-F-H, and Non-Line-of-Sight (NLOS) components will counter fixed-wing and rotary-wing threats in their various tactical profile (standoff, pop up, and close air support). This will be done with the Pedestal Mounted Stinger (PMS) component. FAAD C^2I will collect intelligence and targeting information from organic sensors and other sources, and provide alerting and cuing to FAAD weapon components. Although the battlefield can be viewed as a collection of separate pieces, the overall employment of the FAAD force must be viewed as a system of subsystems interlocked and interwoven to provide total coverage and to permit the enemy no preferred attack option. MANPRINT assessments of each of the FAAD components must be sensitive to this total system concept.

Mission

General Mission. The general mission of the LOS-F-H is to provide air defense to the forward maneuver elements of Armored and Mechanized divisions.

Specific Missions. The specific missions of the LOS-F-H, as stated in the Operational and Organizational (O&O) Plan and the government's LOS-F-H Request For Information (RFI) to contractors, are:

- Defeat low altitude, high performance aircraft;

- Defeat advanced rotary-wing aircraft;

- Defeat ground targets;

- Surveillance;

- Maneuver; and

- Survive.

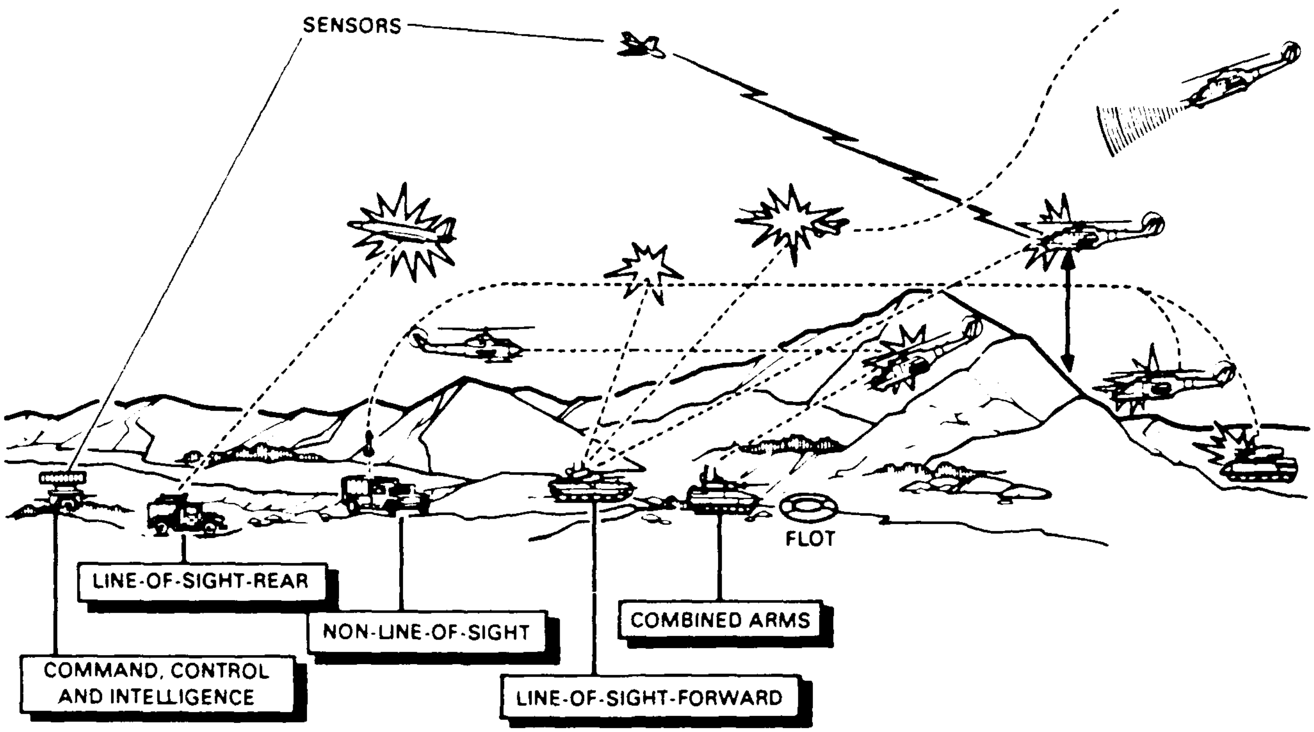


Figure 1. Forward Area Air Defense (FAAD) System

System Description

The LOS-F-H component is to be a self-propelled, armored, highly mobile, air transportable platform with a primary armament of launch-ready missiles and a complementary weapon providing full coverage of air defense within the dead zone of the missile. It will have an integrated ground defense capability for self protection. The weapon will possess a capability for 360 degree target detection and engagement. It will be capable of engaging threat aircraft in all profiles (standoff, attack, run-in, etc.), and be effective in a heavy threat countermeasures environment (electronic countermeasures (ECM), infrared countermeasures (IRCM), etc.). The LOS-F-H component will possess a fully integrated passive detection sensor capable of providing targeting data to the weapon in an autonomous mode of operation with no more than 40 percent degradation in weapon ranging capability. It will incorporate active target identification devices of the FAAD C^2I. These devices will provide positive friend and hostile identification. Emplacement and set-up times from vehicle halt to engagement by the missile subsystem will be minimized. Minimized displacement time after engagement is also required. A shoot-on-the-move suppressive fire capability for the gun subsystem is required. The weapon must use an Azimuth Reference Unit (ARU) to provide an automatic capability to orient on true north to ± 5 degree accuracy. Reload of the weapon must be accomplished by the crewmembers within 15 minutes in day or night environments. The LOS-F-H component will provide full performance in a climatic range from -25 degree to 140 degree Fahrenheit (including solar radiation).

The major subsystems of the LOS-F-H are:

- Fire Control;
- Command, Control, and Intelligence;
- Armament;
- Turret;
- Power and Actuator; and
- Chassis.

Each of the major subsystems is briefly described in the following sections.

Fire Control. The fire control subsystem consists of the passive, day/night detection, tracking, integrated IFF (Identification Friend or Foe), automatic ranging and fire control computer. All subsystems are fully integrated with the fire control system and capable of providing detection, acquisition, tracking, ranging and firing from on-board.

Command, Control and Intelligence. The LOS-F-H weapon will interface with the C^2I component of the FAAD system. Targeting information and command and control will be provided by the Enhanced Position Location Reporting System (EPLRS). Voice backup and amplification of command and control information will be provided by the Single Channel Ground to Air Radio System (SINCGARS).

Armament Subsystems. The primary weapon for the LOS-F-H will be at least six launch ready missiles capable of day/night engagement. A secondary gun subsystem will provide coverage in the missile dead zone and self defense against ground troops. The gun subsystem must carry a stowed load sufficient for at least 20 engagements of aerial targets.

Turret Subsystem. The turret houses the turret/armament drive systems, all sensor C^2I/integrated data displays and major equipment mounts. The weapon will possess a capability for 360 degree target detection and engagement. The turret subsystem will be hardened for operations and survival in a hostile battlefield environment providing survival against dust, smoke, nuclear, biological, chemical (NBC), ECM, small arms fire, and fragmentation.

Power and Actuator Subsystem. Turret and armament positioning is provided by a direct current electro-servo system. Detection, C^2I, tracking, ranging and fire control electronics are powered by a rechargeable battery. Both the recharging auxiliary motor and the main engine use diesel fuel.

Chassis Subsystem. The LOS-F-H will be incorporated into a self-propelled carrier with mobility and armor protection equivalent to the Bradley Fighting Vehicle. The LOS-F-H will be capable of operations and survival in the hostile battlefield environment (i.e., dust, smoke, ECM). The weapon, minus the missile in flight, will be hardened against the effects of electromagnetic pulse (EMP). It must meet the standards of AR 70-71 for NBC survivability. The weapon must be decontaminable utilizing materials that resist contaminant absorption and designed to allow easy access to exposed surfaces for decontamination. The weapon must be hardened to prevent material damage to components by either agents or decontamination procedures and materials.

Acquisition Strategy

The acquisition strategy for the LOS-F-H System is Non-Developmental Item (NDI). NDI is a generic term that defines a system which uses demonstrated and emerging technologies from a variety of sources with little or no development effort by the Army. The formal categories of NDI acquisition are listed below:

1. Category A - Off-the-shelf items that are to be used in the same environment as commercial use.

2. Category B - Off-the-shelf items that are to be used in a military environment substantially different from a commercial environment.

3. Category Other - A new system assembled from components that are in use in a variety of environments (commercial - U.S. or foreign; military - U.S. or NATO). The system requires integration by a manufacturer and may require some hardware and/or software development.

The LOS-F-H is a Category Other NDI acquisition. Most of the components exist but will require integration and some fabrication by the manufacturer. The fact that LOS-F-H is an NDI acquisition has important implications with respect to MANPRINT. In NDI, the materiel system is not developed in response to a particular set of functional requirements nor designed to specific performance objectives. Rather, a judgment will be made that the various available components will be effective in addressing a set of mission deficiencies. The materiel system may rely heavily on pre-planned product improvement (P^3I) to obtain a desired capability, assuming that the basic configuration of the system is intrinsically sound. The manufacturer may be able to improve on system performance through integration, hardware modification and software design. However, the object is not to design and develop the system, in traditional terms, in direct response to an identified threat.

SCOPE OF ANALYSIS

Study Objective

As stated by the proponent, the overall objective of the present study was to determine whether soldiers representative of the current personnel pool can effectively operate a hybrid system. While the overall objective appears straightforward, it is more encompassing when viewed from the perspective of MANPRINT. A critical early step is to specify functionally what the total system must do to meet mission requirements and how well it must perform these activities. Given system performance requirements, it is necessary to demonstrate that the system's operability concept (i.e., human-machine function allocation concept) is viable. A related issue concerns system supportability: the Army's ability to provide the MPT resources required by a specific system concept. These concerns are more fully discussed in the next section.

Issues

Four closely related issues are subsumed under the overall issues of operability and supportability.

1. <u>What operator human factors concerns exist in these surrogate systems? (Human factors engineering (HFE) "fit", systems safety (SS), and health hazards (HH).)</u>

Human factors concerns consist of all of the elements in the system's environment that influence operator capabilities and limitations. The specific concerns that were investigated in the present analysis include:

- Anthropometry;
- Man System interface (controls and displays);
- Potential health hazards; and
- Potential system safety hazards.

2. <u>What performance is required of operators and are these requirements supportable? (Operator in Action.)</u>

For a system similar to LOS-F-H, the encompassing MANPRINT question is, "can this soldier, with this training, perform these tasks, to these standards under these conditions?" This issue was addressed through an examination of the surrogate systems' human-machine interaction to insure that performance standards could be met within the limits of training resources, aptitudes, skills, physical capabilities and physiological tolerances.

3. Is the human-machine function allocation scheme viable given the proposed operating environment? (Operator in Tactical Action.)

System performance is a combination of individual and equipment performances and is further impacted by operational and environmental conditions. The functional allocation concept for the LOS-F-H was evaluated using time-line (contractor-provided) and operator workload (OWL) analyses.

4. What are the system's MPT requirements, and can the Army meet these requirements? (Numbers, Quality, and Training.)

MPT affordability concerns the proponent's ability to provide sufficient numbers of people with the right aptitudes and training for effective system performance. While MPT requirements are often a single focus, this area is best analyzed in terms of (1) manpower and personnel requirements, and (2) training requirements. Manpower and personnel concerns deal with defining organizational structure, manning requirements, and personnel qualifications. Manpower requirements are typically addressed at three levels: weapon system, organization/unit, and total force.

Training requirements concern the subject content and time required to impart the requisite skills and knowledges to qualify a person to use, operate, maintain, or support a system. In its broadest context, training impacts on the Army personnel system, tactical employment concepts, the logistics system, and the Army budgeting program.

Limitations and Constraints

Resource Documents

The primary document used for evaluating system requirements was the O&O Plan. At the time the analysis began, the Required Operational Capability (ROC) had not been written. The analysis is, therefore, based on the limited planning documentation available early in the acquisition process. The impact of this limitation is that the system description may lack detail that has since been developed.

Documentation on the system surrogates was provided by the manufacturers and consisted primarily of their responses to the Army's RFI. Supplemental information was provided when requested and consisted of studies relating to human factors, system safety, operational time-lines, and task list data.

Hardware Systems

Fully developed systems were expected to be available for inspection at the manufacturers' facilities. However, only non-operational, partially configured systems were available.

Analysts were not able to perform a complete hands-on evaluation of the hybrid systems in order to gain an appreciation for the complexities of system operation. A "feel" for these complexities had to be developed through interviews with the manufacturers' engineers.

Time

Approximately 30 days were available in which to gather and analyze project data. During this time, four separate trips to manufacturers' facilities were conducted. As a result of the time limitations, not all of the inconsistencies identified during the MANPRINT evaluation were completely resolved. Specific issues that will require study during future MANPRINT analysis are described at the end of this report under Discussion and Recommendations.

TECHNICAL APPROACH

Overall Approach

Given the short period of time available to conduct the surrogate assessment, the analysis had to be conducted using data available from manufacturers or government sources, quickly organized briefings by manufacturers, and visual observations and structured "walk throughs" on equipment located at the manufacturers' facilities. Sufficient time was not available to carry out primary data collection.

The actual analysis was conducted in four phases, described as follows:

1. Front End Analysis (FEA)
2. System Operability Assessment
3. MPT Affordability Assessment
4. Operability/Affordability Integration

Each phase is described briefly in succeeding paragraphs.

Front End Analysis (FEA)

The purpose of the FEA was to gather background information on the functional requirements and performance requirements for the LOS-F-H surrogate systems. The first part of the FEA began with a review of the O&O Plan and the Army's doctrine for FAAD employment. This provided an overview of the system's mission requirements and a description of the operational environment. Functions required in support of the mission were identified and analyzed to the level necessary to determine performance requirements for the system. The manufacturers' responses to the government's RFI on each of the surrogate systems served as a basis for mapping functions to hardware, software, and human operators. The results of the FEA provided for a definition of the system concept and an information store on which to base the remaining analyses.

System Operability Assessment

Operator Performance Requirements

Operator performance requirements were identified through a time-line analysis of the engagement sequence. This evaluation provided a basis for assessing the ability (with the operator in action) of each surrogate to perform effectively against the anticipated threat. The task analysis was based on the functional requirements that were identified during the FEA. Each surrogate's allocation of functions to equipment, software and operator was further examined to determine whether the allocation scheme placed an unreasonable burden on the operator. In this regard, a hypothetical manual system (50 caliber machine gun) and four systems with varying levels of automation (Vulcan, Air Defense Gun-Missile-1 (ADGILE-1), Mobile Weapon System (MWS), and Light-Armored Vehicle-Air Defense (LAV-AD)) were used as a basis for comparison. These systems were used in the analysis because earlier tests had demonstrated that these recent systems could be operated in a manual mode with little observed operator difficulty.

In each case, OWL was estimated using a technique developed by McCracken and Aldrich (1984). A composite OWL score was derived for each system, based upon evaluations of existing test reports and system descriptions. Six "subject matter experts," familiar with each system through analysis of available information, rated the different critical engagement sequence tasks for operational difficulty. While time estimates were not available for all systems, for purposes of this analysis it was assumed that such tasks as tracking or ranging would take equal amounts of time on each system, that is, would be largely a function of target characteristics. Between-systems differentiation was assumed to come from differing levels of task automation. In view of the lack of availability of more specific data, this approach afforded the most direct way to incorporate OWL concerns into the surrogate analysis.

Human Factors Engineering/System Safety/Health Hazards Evaluations

A human factors engineering evaluation was completed using the guidance provided in MIL-H-46855B (Human Engineering Requirements for Military Systems, Equipment and Facilities) and MIL-STD-1472C (Human Engineering Design Criteria for Military Systems, Equipment and Facilities). The assessment was conducted by HEL in response to the issue of the human's "fit" to the system. Various operational and environmental conditions that could be expected to occur in the system's operation and design deficiencies that did not meet MIL-STD-1472C guidelines were examined for their potential impact on individual performance. Health hazards and system safety assessments were conducted to insure that the systems were intrinsically safe to operate and maintain. These were generally conducted in a limited checklist fashion, since it was not possible to conduct extended dynamic analyses on the prototype, unassembled systems.

MPT Affordability Assessment

Following the assessment of system operability, analyses were conducted to determine whether sufficient numbers of soldiers were available with the right aptitudes and training for effective system performance. The MPT affordability assessment was performed in two steps: (1) manpower and personnel analysis, and (2) training requirements analysis.

Manpower and Personnel Analysis

The objectives of the manpower and personnel analysis were to: (1) identify the number of operators required to operate a single surrogate system, and (2) determine whether the current Air Defense military occupational specialty (MOS) structure can accommodate these requirements. Manpower requirements for the crew were determined based on tactical, scenario-driven operational requirements. Job requirements were identified by comparing the current Air Defense MOS structure with the surrogate systems' operator skill requirements. Manpower requirements were then compared with projected allocations for the LOS-F-H.

Training Requirements Analysis

LOS-F-H training requirements were identified using principles congruent with the Army's Systems Approach to Training. The objective of the analysis was to identify the "what, where, and how" of training in sufficient detail to determine if there are potentially unsupportable training burdens for the LOS-F-H. The procedures determined to be appropriate for this analysis are briefly described in the paragraphs that follow.

Task Analysis. A preliminary task analysis was conducted as part of the FEA. A review of each of these tasks was carried out to insure that it qualified as a legitimate task statement (specific action, definite beginning and end, measurable, performed in a relative short period of time, and performed for its own sake). As all preliminary tasks met these requirements, all were selected for training. Each task was then evaluated to determine those tasks that will initially be taught in the institution and those tasks that will be taught in units. Tasks were also evaluated with respect to initial, transition, sustainment, and/or collective training requirements. In addition, preliminary training device requirements were determined.

Training Program Development. In order to structure a strawman LOS-F-H training program, tasks were clustered into training modules. The course summary developed for the training program provided sufficient information to address training issues on a comparative basis to include: (1) the suitability of the training concept, (2) a preliminary assessment of training requirements, (3) potential training problems, (4) potential remedies for these problems, and (5) an analysis of the Army's ability to implement training remedies.

Operability/Affordability Integration

The integration of operability and affordability issues was based on the following questions.

- Can a soldier representative of the current personnel pool operate a hybrid system effectively?
- Can the Army afford the MPT burden?
- Can improvements to system operability be made?
- What can be done to decrease the MPT burden?

STUDY RESULTS

Results of Front End Analysis

Functional Requirements

The front end analysis provided the framework for the remainder of the analyses. As a starting point, the missions outlined in the O&O Plan were reviewed and used to identify system functional requirements. Functions required in support of the system's mission are presented in Table 1.

Following the identification of functions and sub-functions, performance measures and performance standards were developed. Table 2 presents a listing of functions with the applicable performance measures and performance standards. Since the study dealt only with operators, only those measures and standards that apply to operators have been identified. An "ns" notation in the performance standard column indicates that "no standard" has been identified.

Function Allocation

Before functions could be allocated to hardware, software and operators, an equipment structure had to be identified. Table 3 presents a listing of generic equipment by major subsystems defined for the LOS-F-H. Table 4 is a listing of the functions allocated to hardware/software and operator. Because most of the system functions are integrated through a computer, allocations to hardware and software were combined under a single heading.

Table 1. LINE OF SIGHT-FORWARD (HEAVY) FUNCTIONS

Functions	Sub-funfunctions
Shoot	Aim Acquire Target Determine Range Track Target Load Select Weapon Charge Weapon Fire Weapon
Move	Transit Navigate
Communicate	Transmit Receive
Command, Control and Intelligence	Search Detect Identify/Classify Disseminate
Sustain	Rearm Ammunition Maintain Inspect Isolate Replace Repair Adjust Service Preventive Maintenance Checks and Services (PMCS) Evacuate Power
Survive	Minimize Signature Visual Thermal Acoustic Electronic Radar NBC Environment Ballistic Penetration

Table 2. LINE OF SIGHT-FORWARD (HEAVY) FUNCTIONAL REQUIREMENTS

Function	Performance Measure	Standard
Shoot	Acquire target (per day)	11
	Range target (per day)	11
	Track target (per day)	11
	Select weapon (per day)	11
	Engage target (per day)	3
	Rate of fire for 1 target	
	- Gun	3 bursts
	10 rounds per burst	
	- Missile	1
	Accuracy for 1 target	
	- Gun	ns
	- Missile	ns
Move	Kilometers per day	60
	Hours of engine operation	3
	Displacement time seconds (sec)	Minimum: ns
		Maximum: ns
	Emplacement time (sec)	Minimum: ns
		Maximum: ns
Communicate	Hours per day	17
Command, Control & Intelligence	Surveillance hours	17
Sustain	Reload Time (minutes)	15
	Operating hours per day	6
	Maintenance hours (PMCS)	ns
Survive	Mask/hide/engage	90%
	Shoot on the Move	10%

Table 3. LINE OF SIGHT-FORWARD (HEAVY) GENERIC EQUIPMENT LIST

- Fire Control Subsystem
  - Fire Control Computer
  - Commander's Console
  - Gunner's Console
- Command, Control and Intelligence Subsystem
  - Enhanced Position Location Indicator
- Communications Subsystem
  - Radio
  - Intercom
- Armament Subsystem
  - Missile
  - Gun
- Turret Subsystem
  - Environmental control unit
  - Armament drive systems
- Power and Actuator Subsystem
  - Electro-servo module
  - TV
  - FLIR
  - Battery recharger
- Chassis
  - Armored track vehicle
  - Engine

Design Differences

Design differences were identified in order to explain any differences in performance requirements between the baseline (generic) system identified from the descriptions in the O&O Plan and those performance capabilities of the surrogate systems. Design similarities and differences are indicated in Table 5. Essentially, there were few basic design differences identified based on information available.

Preliminary Task Identification

The functions allocated to the operator, either alone or in combination with hardware and software, are the activities that form the basis for task identification. The generic activities identified through the allocation of functions (identified in Table 4) become tasks when they are analyzed as an integral part of the surrogate system. The preliminary tasks required of the operator were assigned in a single step process through use of

Table 4. LINE OF SIGHT-FORWARD (HEAVY) FUNCTION ALLOCATION

Functions	Sub-functions	Hardware/Software	Operator
Shoot	Aim		Aim
	Acquire Target	Electro-Servo Module	Operate Console
	Determine Range	Electro-Servo Module	Operate Console
	Track Target	Electro-Servo Module	Operate Console
	Load		Load
	Select Weapon	Missiles/Gun	Operate Console
	Charge Weapon	Fire Control Computer	Operate Console
	Fire Weapon	Fire Control Computer	Operate Console
Move	Transit	Armored Track Vehicle	Drive Vehicle
	Navigate	Armored Track Vehicle	Drive Vehicle
Communicate	Transmit	Radio/Intercom	Operate Radio/Intercom
	Receive	Radio/Intercom	Operate Radio/Intercom
Command, Control and Intelligence	Search	EPLRS	Monitor EPLRS
	Detect	EPLRS	Monitor EPLRS
	Identify/Classify	EPLRS	Monitor EPLRS
	Disseminate	EPLRS	Monitor EPLRS

Table 4. LINE OF SIGHT-FORWARD (HEAVY) FUNCTION ALLOCATION (Continued)

Functions	Sub-functions	Hardware/Software	Operator
Sustain	Rearm	Missiles/Gun	Reload
	Ammunition	Missiles/Gun	Load Missiles/Gun ammo
	Maintain		Perform PMCS
	Inspect	Computer -* BIT/BITE	Operate Console
	Isolate	Computer -* BIT/BITE	Operate Console
	Replace		Replace
	Repair		Repair
	Adjust		Adjust
	Service		Service
	PMCS		Perform PMCS
	Evacuate		Evacuate
	Power	Engine	Operate Engine
Survive	Minimize Signature		
	Visual	Armored Track Vehicle	Hide Vehicle
	Thermal	Armored Track Vehicle	Stop Vehicle
	Acoustic	Armored Track Vehicle	Stop Vehicle
	Electronic	Primary Power Unit (PPU)	Turn off Power
	Radar	Radar	Turn off Radar
	NBC	Protective Equipment	Wear Protective Equipment
	Environment	Protective Clothing	Wear Protective Clothing
	Ballistic Penetration	Armored Track Vehicle	Armored Track Vehicle

*BIT/BITE = Built In Test/Built In Test Equipment.

Table 5. LINE OF SIGHT-FORWARD (HEAVY) EQUIPMENT DESIGN DIFFERENCES

Generic Equipment Identification	Surrogate 1	Surrogate 2
Fire Control Subsystem	Fire Control Subsystem	Fire Control Subsystem
Fire Control Computer	Fire Control Computer	Fire Control Computer
Commander's Console	Commander's Console	Commander's Console
Gunner's Console	Gunner's Console	Gunner's Console
C^2I Subsystem	C^2I Subsystem	C^2I Subsystem
Enhanced Position Location Indicator	Not Integrated	Not Integrated
Radar	Radar	Radar
Not Specified	Integrated Pulse Acq	Integraded Pulse Acq
Communications Subsystem	Communications Subsystem	Communications Sybsystem
Radio	SINCGARS Radio	SINCGARS Radio
Intercom	Intercom	Intercom
Armament Subsystem	Armament Subsystem	Armament Subsystem
Missiles	Beam Guided Missiles	Beam Guided Missiles
		Heat Seeking Missiles
Gun	25MM Gun	25MM Gun
Turret Subsystem	Turret Subsystem	Turret Subsystem
Environmental control	Environmental Control	Environmental Control
Armament drive systems	Armament Drive System	Armanent Drive System
Power and Actuator Subsystem	Power and Actuator Subsys	Power and Actuator Subsys
Electro-servo module	Electro-servo module	Electro-servo module
TV	TV	TV
FLIR	FLIR	FLIR
Battery recharger	Battery Recharger	Battery Recharger
Chassis	Chassis	Chassis
Armored track vehicle	Bradley M2	Bradley M2

the functional allocation list, the RFI responses from the manufacturers, and interviews with manufacturer engineers. These tasks are listed by major subsystems in Table 6.

Results of System Operability Analysis

Operator Performance Requirements

Performance requirements for the operator were first addressed in a time-line assessment of the LOS-F-H engagement sequence, illustrated in Figure 2. The data for the operational time-line were obtained primarily through interviews with contractor engineers. Procedures demonstrated on the system consoles were observed to determine if there were complexities in the sequence that would have an impact on operator performance. The time required to perform the engagement sequence by the commander and gunner was approximately 20 seconds. This time permits the crew to engage a high performance fixed-wing aircraft traveling at 600 knots and detected at a distance beyond six kilometers.

A second analytical procedure directed at the issue of operability involved estimating OWL. OWL for the LOS-F-H surrogate, the hypothetical manual system, and four comparable systems (Vulcan, ADGILE-1, MSW, and LAV-AD) was determined. OWL was estimated using a technique developed by McCracken and Aldrich (1984). Table 7 lists the workload components utilized in their approach. For each of the systems in this comparison, the tasks in the engagement sequence were assigned an OWL rating based on known system characteristics. An illustration of the workload rating procedure applied to one of the comparative systems is shown in Table 8.

The results of this workload comparison are shown in Table 9. Note that in the manual system, all of the tasks required in the engagement sequence were assigned to the operator, and in the LOS-F-H, only the essential manual tasks were assigned to the operator. For this discussion, workload was seen as a zero-sum quantity; that is, a task had to be carried out by some entity, be it operator or equipment/software. The workload ratings signify what is required for a human operator to do the job. The equipment/software or machine workload rating indicates the "unburdening" of workload from the human operator to equipment/software. The results indicate that if the LOS-F-H's automated functions work as intended, OWL should not be excessive. Figure 3 is a simplified bar chart illustrating the task allocation and distribution of workload between the human operator and machine for each of the evaluated systems.

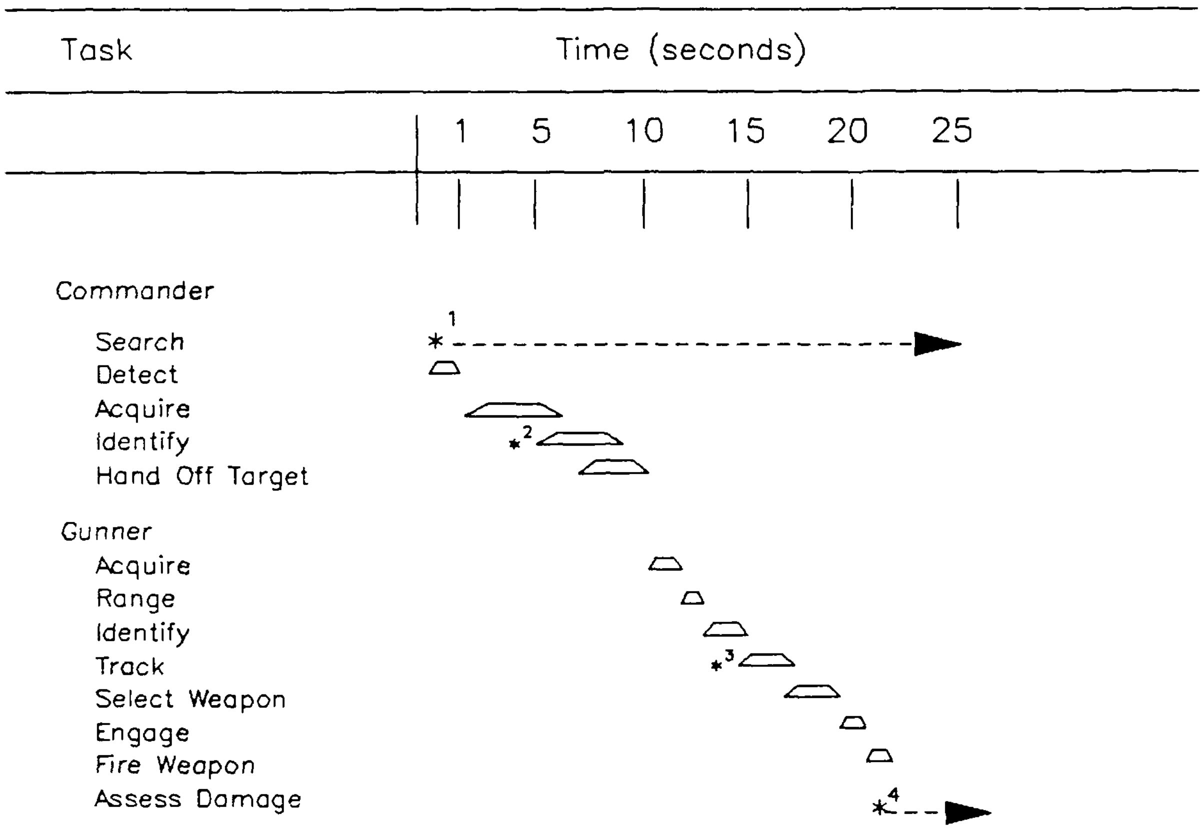
Results of Human Factors Engineering, System Safety, and Health Hazards Evaluations

As noted earlier, HFE/SS/HH assessments of the two surrogate systems were conducted by HEL. These analyses were in response to the issue of the human's fit to the system. The

Table 6. TASK LIST - LOS-F-H SURROGATE SYSTEM

Fire Control Subsystem
Operate Radar/Commander's Console
Operate Radar in Alternate Mode (other than default)
Operate Optical Sight
Power and Actuator Subsystem
Operate the Electro-Servo Module
Boresight the Electro-Servo Module
Operate the TV Sensor
Operate the FLIR Sensor
Operate the Laser-Ranger Assembly
Turret Subsystem
Change Gas Bottle
Lock/Unlock Travel Locks
Armament Subsystem
Load/Reload Missiles
Load/Reload Gun
Stow Missiles
Stow Gun Ammunition
Boresight Gun
Align Gun
C^2I and Communication Subsystems
Operate C^2I System Equipment
Operate SINCGARS Radio
Operate Intercom
Vehicle Subsystem
Drive Vehicle
Refuel Vehicle
Operate Land Navigation System
Operate M13 NBC Filters
Operate Smoke Grenade Launcher
Operate Engine Grill Covers
Operate Power Distribution System
Operate Ventilation System
Operator Maintenance
Perform PMCS
Perform System Operation Verification Test with BIT
Detect/Isolate Failure
Replace lowest replaceable unit (LRU)

observations thus obtained are related to the separate systems being evaluated, and refer to the various anticipated operational and environmental conditions, and to design deficiencies that failed to meet MIL-STD-1472C guidelines. It



Note 1. Search is a continuous action. Commander monitors screen and makes minor adjustments to lobe selection and change of clutter mode.

Note 2. Current doctrine requires the Commander to positively identify aircraft before handing off target to the gunner. If the doctrine is not changed for this system, additional time to engage a target will be required and the Commander must be able to use the on–board passive detection devices.

Note 3. Where manual tracking is an option, the procedure will require approximately 1 1/2 seconds longer than automatic function.

Note 4. Beam guided missiles must be guided to the target and, therefore require approximately 18 seconds before Gunner can assess damage and acquire new target, or re–acquire previous target.

Figure 2. ENGAGEMENT SEQUENCE TIME–LINE for the LOS–F–H SURROGATE SYSTEM

Table 7. Rating Scale Values and Descriptors for each of Four Workload Components

SCALE VALUE	DESCRIPTORS
	VISUAL
1	MONITOR, SCAN, SURVEY
2	DETECT MOVEMENT, CHANGE IN SIZE BRIGHTNESS
3	TRACE, FOLLOW, TRACK
4	ALIGN, AIM, ORIENT ON
5	DISCRIMINATE SYMBOLS, NUMBERS, WORDS
6	DISCRIMINATE BASED ON MULTIPLE ASPECTS
7	READ, DECIPHER TEXT, DECODE
	AUDITORY
1	DETECT OCCURRENCE OF SOUND, TONE ETC.
2	DETECT CHANGE IN AMPLITUDE, PULSE RATE PITCH
3	COMPREHEND SEMANTIC CONTENT OF MESSAGE
4	DISCRIMINATE SOUNDS ON THE BASIS OF SIGNAL PATTERN PITCH, PULSE RATE, AMPLITUDE
	COGNITIVE
1	AUTOMATIC (SIMPLE ASSOCIATION)
2	SIGN/SIGNAL RECOGNITION
3	ALTERNATIVE SELECTION
4	ENCODING /DECODING, RECALL
5	FORMULATION OF PLANS (PROJECTING ACTION SEQUENCE,ETC.)
6	EVALUATION (CONSIDER SEVERAL ASPECTS IN REACHING JUDGMENT)
7	ESTIMATION, CALCULATION, CONVERSION
	PSYCHOMOTOR
1	DISCRETE ACTUATION (BUTTON, TOGGLE, TRIGGER)
2	DISCRETE ADJUSTIVE (VARIABLE DIAL, ETC.)
3	SPEECH USING PRESCRIBED FORMAT
4	CONTINUOUS ADJUSTIVE (FLIGHT CONTROLS, SENSOR CONTROL, ETC.)
5	MANIPULATIVE (HANDLING OBJECTS, MAPS, ETC.)
6	SYMBOLIC PRODUCTION (WRITING)
7	SERIAL DISCRETE MANIPULATION (KEYBOARD ENTRIES)

is not the objective of this analysis to evaluate or rate these systems but rather to point out those concerns that could detract from the ability of a soldier representative of the current personnel pool to operate a similar system. The results of the assessment of these prototype systems are summarized

Table 8. LAV-AD Workload Rating

HUMAN OPERATOR WORKLOAD	SEARCH	4 - P
		2 - V
	DETECT	2 - V
	ACQUIRE	4 - P
	IDENTIFY	6 - C
	SELECT WPN	1 - P
		1 - V
		3 - C
	MONITOR TRACK AND RANGE AUTO	2 - V
	FIRE	1 - A
		1 - P
	DAMAGE EVAL	6 - C
SUBTOTAL		33
HARDWARE/ SOFTWARE WORKLOAD	TRACK	11 - V
	RANGE	7 - V
SUBTOTAL		18
TOTAL WORKLOAD		51

V = VISUAL P = PYSCHOMOTOR C = COGNITIVE A = AUDITORY

here. A complete report of the human factors engineering and system safety evaluation conducted by HEL is included in the appendix.

Human Factors Engineering Evaluation

The human factors engineering evaluation indicated the following representative types of problems (See Appendix):

Workspace. Two problems were noted in the workspace:

1. Contractor-provided drawings indicate that the 95th percentile male cannot be accommodated in a sitting position. The problem is compounded by the addition of individual and organizational items of clothing and equipment.

2. Hatch width does not meet the requirements of MIL-STD-1472C.

Missile Loading. The missiles weigh approximately 150 pounds each, requiring a two-man lift or the addition of an automated lifting mechanism for reloading.

Table 9. LOS-F-H Task Allocation Analysis

TASK ALLOCATION	LEVELS of AUTOMATION					
	MANUAL	VULCAN	ADGILE-1	MWS	LAV-AD	LOS-F-H
HUMAN OPERATOR	SEARCH DETECT ACQUIRE IDENTIFY TRACK RANGE FIRE DAMAGE EV	SEARCH DETECT ACQUIRE IDENTIFY TRACK MONITOR FIRE DAMAGE EV	SEARCH DETECT ACQUIRE IDENTIFY TRACK SELECT WPN MONITOR FIRE DAMAGE EV	SEARCH DETECT ACQUIRE IDENTIFY TRACK SELECT WPN MONITOR FIRE DAMAGE EV	SEARCH DETECT ACQUIRE IDENTIFY SELECT WPN MONITOR FIRE DAMAGE EV	ACQUIRE SELECT WPN MONITOR FIRE DAMAGE EV
HUMAN OPERATOR WORKLOAD RATING	34	29	37	39	33	18
EQUIPMENT/ SOFTWARE		RANGE	RANGE	RANGE	RANGE	SEARCH DETECT ACQUIRE IDENTIFY TRACK RANGE SELECT WPN
EQUIP/SOFTWARE WORKLOAD		11	11	11	18	36
SYSTEM WORKLOAD	34	40	48	50	51	54

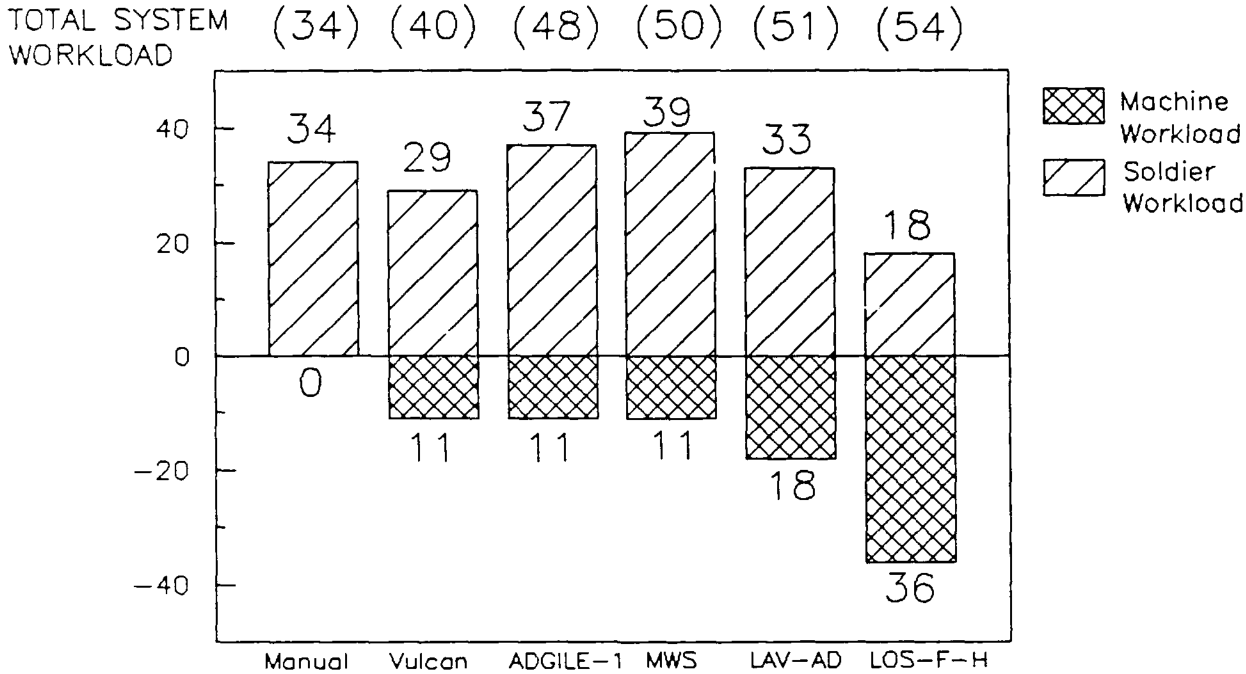


Figure 3. Soldier−Machine Task Allocation and Effect on Workload Ratings

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<u>Controls and Displays</u>. Four problems were noted in the operator console:

1. The commander and the gunner have different tasks but their workstations have identical controls. This condition could result in negative transfer when operators are required to move from one console to the other in switching jobs.

2. A keypad is used to enter system function codes at both workstations but no on-screen menu is provided. This condition requires either memorizing the function codes, designing an effective job performance aid, or redesigning of the software. Further evaluation of the method for executing keypad entries of system function codes is recommended.

3. The PPU control panel is presently designed to be located behind the commander and gunner seats. Accessing PPU controls and monitoring displays are therefore difficult tasks.

4. The gunner's engagement task requires a seven-step operational sequence divided between two hand-operated control devices and one foot switch. It is recommended that this method be studied to determine its trainability and impact on system effectiveness.

<u>Speech Intelligibility</u>. A determination of the interior steady-state noise levels created by the surrogate systems could

not be performed. It is recommended that candidate systems undergo dynamic testing to determine speech intelligibility levels.

System Safety and Health Hazards Evaluation

The evaluation of system safety and health hazards indicated that the prototype systems present hazardous conditions that must be further investigated by qualified safety personnel. The following hazards were identified for this analysis:

1. A thermal hazard is produced by the PPU.

2. An electrical hazard is produced by a 115 volt window de-icing system.

3. Hazards are produced by the normal handling of explosive material.

4. Toxic hazards are produced during system operation and missile launch.

5. Hazards are caused by high-velocity gun sabots (ejection of spent shells or packing material) during firing exercises.

Results of MPT Affordability Assessment

MPT affordability were obtained in two steps: (1) manpower and personnel analysis, and (2) training requirements analysis.

Manpower and Personnel Analysis

The objectives of the manpower and personnel analysis were to: (1) identify the number of operators required to operate a single surrogate system; and (2) determine whether or not the current Air Defense MOS structure can accommodate the surrogates' manpower requirements.

Operator Requirements. Using the preliminary task analysis results obtained during the FEA, a tactical operation time-line was developed for emplacement, engagement, and march order tasks. Figure 4 presents the actions required in LOS-F-H tactical operation; the times required to perform driver, commander, and gunner actions; and the simultaneous events that occur for these operations personnel.

The results indicate that a three man crew is necessary to operate the LOS-F-H surrogates. However, the analysis is based principally on the manufacturers' outline for the scheme of operation. The primary alternative to this scheme is the integration of the LOS-F-H and FAAD C^2I components, which is expected to replace the on-board radar. Since the commander's

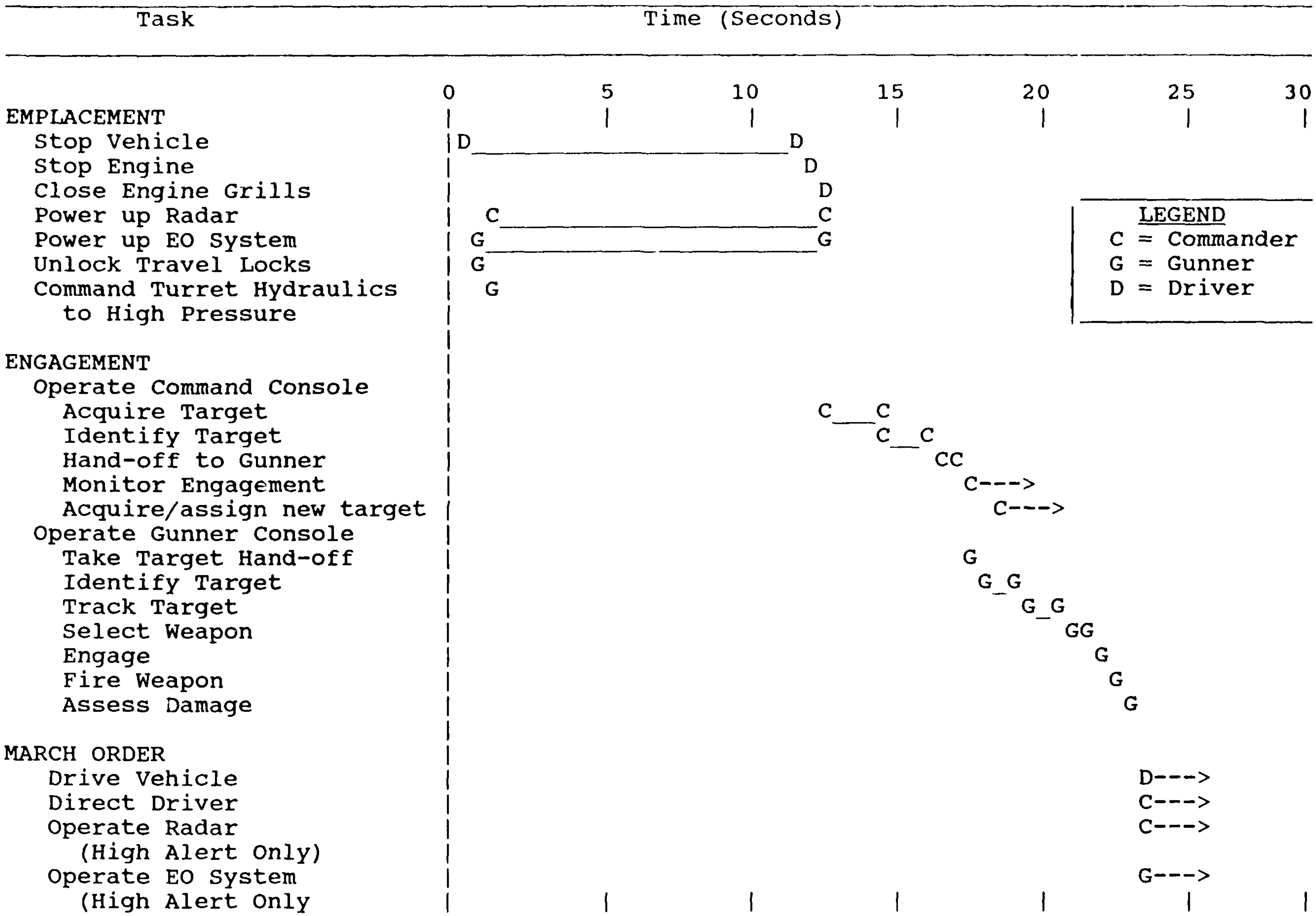

FIGURE 4. TACTICAL OPERATION TIME-LINE

primary job in the operational scheme is to acquire targets with the radar and hand them off to the gunner, elimination of the on-board radar would serve to free the commander to utilize non-cooperative target recognition and C^2I information and set target priorities. Potential ramifications of such task changes were not assessed.

<u>MOS Requirements</u>. It was not expected that job requirements for the surrogate systems would match any existing Short Range Air Defense (SHORAD) MOS, since there are currently no fielded hybrid Air Defense systems. There are, however, a number of systems fielded where the operators perform similar tasks such as operate a console, search, detect, acquire, identify, track, engage, and fire weapons. Table 10 is a listing of current SHORAD MOS requirements. This table indicates the prerequisites for entry level training for each of these MOS. Comparing LOS-F-H tasks common to those in predecessor systems, a tentative prerequisite outline for a LOS-F-H Air Defense Crewman was constructed and is presented in Table 11.

Personnel classified in MOS 16R, Vulcan Crewman, have been identified as the most likely resource from which personnel would be drawn for transition training to LOS-F-H. Prerequisites for entry into MOS 16R are similar to the requirements identified for LOS-F-H (i.e., aptitude area OF score of 100, very heavy physical demands, red/green color discrimination) (see Table 11). A critical prerequisite to satisfy is the aptitude area score. OF scores for current personnel in MOS 16R are shown in Table 12. Although just over 26 percent of these personnel have OF scores below 100, there are sufficient personnel remaining in the inventory to meet the initial manning requirements for the LOS-F-H (at the time of this project, the working figure was a crew of 3 for each of 160 systems, for a total of 480 personnel). However, since manning strength profiles are dynamic, the nature of the target audience must be monitored through to time of fielding.

<u>Training Requirements Analysis</u>

The objective of the training requirements analysis was to identify the "what, where, and how" of the surrogates' training requirements in sufficient detail to determine if there are potentially unsupportable training burdens. The results of the analysis were obtained in two steps: (1) Task Analysis, and (2) Training Program Development.

The preliminary task list developed during FEA was validated for use in determining training requirements. Specifically, each task was reviewed based on the requirement to insure that it qualified as a task statement (as described on p. 10). Based on the current TRADOC policy requiring that 90 percent or more of the tasks selected for training be initially taught in the institution with the remainder to be initially taught in the unit, a training location was obtained for each

Table 10. Current MOS Requirements

Source: AR 611-201, Apr 86

MOS	[a]AA SCORE	PHYSICAL DEMANDS	VISION	[b]PROFILE	SEC CL	ITEMS MAINT
16H	[c]OF 100	[d]M	[e]R/G	222221	[f]S	0
16J	OF 100	M	R/G	222221	S	3
16P	OF 100	[g]VH	R/G	222221	[h]C	6
16R	OF 100	VH	R/G	222221	C	5
16S	OF 90	VH	N	111211	C	2
24M	OF 100/ EL 110	VH	N	222221	C	14
24N	OF 100/ EL 110	VH	N	222221	C	18
27F	[i]EL 100	VH	N	222221	C	24
27G	EL 95	VH	N	222221	C	34
27N	EL 110	VH	N	222221	C	10

ADDITIONAL REQUIREMENTS: Minimum Height of 64 inches
Vision correctable to 20/20 without multifocal lenses

Notes:

a.	AA:	Aptitude Area
b.	Profile:	PULHES (Physical capacity; upper extremities; lower extremities; hearing and ear; eyes; psychiatric. See AR 40-501)
c.	OF:	Operator/Food AA
d.	M:	Medium
e.	R/G:	Red/Green color vision is normal
f.	S:	Secret Clearance
g.	VH:	Very Heavy
h.	C:	Confidential Clearance
i.	EL:	Electronics AA

16-Series: Operators
24-, 27-Series: Maintainers

Table 11. LOS-F-H ADA CREWMEMBER PERSONNEL PREREQUISITE

Active Army, grade E-4 or below
Qualifying OF score of 100
Physical demand rating of very heavy
Color discrimination of red and green
Near and far visual acuity correctable to 20/20
Normal depth perception
Auditory acuity loss no greater than 15db in the 100 to 8,000 hertz range
Motor coordination - finger and manual dexterity
Confidential clearance

task and is presented in Table 13. The unit must train 100 percent of the individual and collective tasks for sustainment of skills. A collective task hierarchy for tactical operations is presented in Table 14. Preliminary training devices and products were also identified. Training device requirements are based on a comparison with similar air defense systems and are listed in Table 15. Proposed LOS-F-H training devices are either currently in the Army inventory or the concept under which they may be obtained has been developed.

Training Program Development. A training program for LOS-F-H institutional training was developed and is summarized in Table 16. The preliminary task analysis identified those tasks to be taught in the institution. From this list, tasks were clustered and tentative course modules were developed. Since a formal instruction program had not been developed on the hybrid concept prototypes, a Quasi Program of Instruction (QPOI) was then developed using as a model the POI that had been developed for MOS 16L, Sgt York Gun System Crewmember. The QPOI course summary was then compared with other USAADASCH training programs on the basis of:

1. Suitability of training concept. The strawman LOS-F-H training concept is consistent with other USAADASCH and TRADOC training concepts.

2. Preliminary assessment of training requirements. The course summary is a reasonable assessment of LOS-F-H surrogate system institutional training requirements.

Table 12. Range of "OF" Scores, MOS 16R MAR 86 Enlisted Master File

SCORES	NUMBER	CUM. NO.	PERCENT
01-69	21	21	.69
70-74	3	24	.78
75-79	8	32	1.04
80-84	12	44	1.44
85-89	99	143	4.68
90-94	262	405	13.27
99-99	394	799	26.18
100-104	413	1212	39.71
105-109	348	1560	51.11
110-114	314	1874	61.40
115-119	223	2097	67.71
120-124	171	2268	74.31
125-129	100	2368	77.59
130-134	46	2414	79.09
135-139	11	2425	79.45
140 and above	8	2433	79.72
No score recorded		619	(20.28)

		3052	

3. Potential training problems. There appear to be no significant problems in training the tasks required to operate the LOS-F-H. Identifying operators capable of utilizing BIT/BITE technology could be a potential problem. At present, however, there appears to be no reason to set an electronics aptitude prerequisite for entry into LOS-F-H training. The actions required of the operator seem no more complex than replacing a fuse in an automobile or a home stereo unit. Personnel prerequisites and training requirements for BIT/BITE technology should be evaluated in more detail prior to fielding of the system.

4. Potential remedies for problems outlined. Better system definition will provide for a more complete task analysis and, subsequently, a better defined training program. A Preliminary Training Effectiveness Analysis (PTEA) should be conducted as soon as possible to further explore system traina ility, potential problems associated with the system's

Table 13. TASK INITIAL TRAINING LOCATION

Task	Training Location Institution	Training Location Unit
Fire Control Subsystem		
Operate Radar/Commander's Console	X	
Operate Radar in Alternate Mode (other than default)	X	
Operate Optical Sight	X	
Power and Actuator Subsystem		
Operate the Electro-Servo Module	X	
Boresight the Electro-Servo Module	X	
Operate the TV Sensor	X	
Operate the FLIR Sensor	X	
Operate the Laser-Ranger Assembly	X	
Turret Subsystem		
Change Gas Bottle	X	
Lock/Unlock Travel Locks	X	
Armament Subsystem		
Load/Reload Missiles	X	
Load/Reload Gun	X	
Stow Missiles	X	
Stow Gun Ammunition	X	
Boresight Gun	X	
Align Gun	X	
Communication Subsystem		
Operate SINCGARS Radio	X	
Operate Intercom		X
Operate C^2I System Equipment	X	
Vehicle Subsystem		
Drive Vehicle		X
Refuel Vehicle		X
Operate Land Navigation System	X	
Operate M13 NBC Filters	X	
Operate Smoke Grenade Launcher	X	
Operate Engine Grill Covers	X	
Operate Power Distribution System	X	
Operate Ventilation System	X	
Operator Maintenance		
Perform PMCS	X	
Perform System Operation Verification Test with BIT	X	
Detect/Isolate Failure	X	
Replace LRU	X	

Table 14. Collective Tasks for Tactical Operations

Task	Crewmember Cmmdr	Gnnr	Drvr
EMPLACEMENT			
Stop Vehicle			X
Stop Engine			X
Close Engine Grills			X
Power up Radar	X		
Power up EO System		X	
Unlock Travel Locks		X	
Command Turret Hydraulics to High Pressure		X	
ENGAGEMENT			
Operate Radar	X		
Operate EO System		X	
MARCH ORDER			
Drive Vehicle			X
Direct Driver	X		
Operate Radar (High Alert Only)	X		
Operate EO System (High Alert Only)		X	
RELOAD			
Position Turret to Reload Position		X	
Lock Travel Locks		X	
Depress Reload Button	X		
Loosen Canister Clamps			X
Remove and Discard Spent Canisters	X	X	
Place Missile Rounds in Yoke	X	X	
Tighten Canister Clamps			X
Test Cables for no Voltage		X	
Cable Missiles		X	
Tighten Canister Clamps			X
Load Gun Ammunition in Gun	X	X	
Stow Missiles in Vehicle	X	X	
Stow Gun Ammo in Vehicle	X	X	
Depress Reload Button	X	X	
REFUEL			
Stop Engine			X
Remove Fuel Caps			X
Install Fuel Hose in Tank			X
Fuel Tanks			X
Assist Driver		X	

Table 15. PRELIMINARY TRAINING DEVICES AND MATERIALS

INSTITUTION
Conduct of Fire Trainer (COFT)
2D/3D Integrated Video Disc
Dummy/Smart Missile Simulators
Launch Simulator
UNIT
Soldier's Manuals
Job Books
Situational training exercise (STX)/Drills
Army training and evaluation program(ARTEP)
Common Troop Proficiency Trainer
2D/3D Integrated Video Disc
Dummy/Smart Missile Simulators
Launch Simulator
1/5 Scale Targets
Combat Tables
Multi-purpose Range Complex

technological complexity, individual mental category and aptitude requirements associated with the training strategy, and availability of personnel to field and sustain the system.

5. An analysis of the Army's ability to implement training remedies. There appear to be no significant complexities in the LOS-F-H that would require specific training remedies that are beyond the Army's ability to resolve. Caution is suggested, however, because of the type of procurement (i.e., NDI). Training must not be permitted to become an automatic solution to performance problems that cannot be readily resolved through equipment or software modifications. Other avenues of improvement must also be taken into account, such as engineering change proposals (ECPs), a different mix of (MOS), as well as optimizing of function allocation through effective automation of operator tasks or software redesign.

Operability and Affordability Integration

Based on the operability and affordability assessments of the LOS-F-H surrogate systems, it can be stated that soldiers representative of the proposed personnel pool can operate a hybrid system effectively. This conclusion is based in part on reductions in OWL brought about through automation. Operator performance requirements on the LOS-F-H surrogate systems appear reasonable since the majority of complex tasks are automated.

Table 16. Course Summary

16X10-OSUT, Line of Sight Forward (Heavy)
Air Defense System Crew Member

ANNEX	SUBJECT:	PEACETIME	MOBILIZATION
A	Introduction to LOS-F(H) Air Defense System	11 Hours	TBD
B	Visual Aircraft Recognition	32 "	TBD
C	Threat Vehicle Recognition	28 "	TBD
D	Operate/Maintain Track Vehicle	57 "	TBD
E	Subsystems of LOS-F(H) AD System	33 "	TBD
F	Prepare System for Operations	32 "	TBD
G	Gun Operations and PMCS	56 "	TBD
H	Missile Operations and PMCS	44 "	TBD
I	Engagement sequence	37 "	TBD
J	Combat Scenarios	16 "	TBD
K	During system Operations	32 "	TBD
L	Engagement with Degraded Equipment and Auxiliary Duties	36 "	TBD
M	Range Firing	32 "	TBD
N	Review & End of Course Test Vehicle/Communications	12 "	TBD
O	Review & End of Course Test LOS-F(H) Peculiar	20 "	TBD
SUBTOTAL		478 Hours	

COURSE LENGTH:

PEACETIME - 13.3 Weeks MOS Training

MOBILIZATION - TBD

ACADEMIC HOURS BY TYPE OF INSTRUCTION

ANNEX	CONF	PE 1	PE 3	E1	E2	E3	
A	5	4	2				
B			30		2		
C			24		4		
D	1	48		8			
E	11	19		2		1	
F	11	18		2		1	
G	12	38		4		2	
H	10	30		3		2	
I	16	18		2		1	
J		16					
K	8	21		2		1	
L	11	22		2		1	
M		32					
N	4			8			
O	2	8		8		2	
TOTAL HOURS	91	274	56	41	6	10	(478)

PERCENT OF INSTRUCTION: Active 69%: Passive 19%; Evaluation 12%.

There are deficiencies in the areas of human factors engineering, system safety, and health hazards that if left uncorrected could reduce the performance capabilities of the operator. Manufacturers must follow the guidance provided in MIL-H-46855B and MIL-STD-1472C to insure that systems being acquired by the Army create the least burden possible on the operator. The HFE/SS/HH concerns identified in the surrogate systems are not sufficient to preclude effective operation of the systems. These concerns do not appear to directly affect the viability of the hybrid concept as demonstrated in the surrogate systems.

Manpower requirements do not exceed the identified resources available to man the system. HARDMAN analyses of manpower requirements for the Sgt York System were based upon the requirement for a three man crew, as is needed for the LOS-F-H. The total force requirements for LOS-F-H have, however, been reduced from what was planned for the Sgt York. Hence, on the basis of previously planned manpower allocations, there are adequate operator manpower resources to field the LOS-F-H.

As stated above, the hybrid concept appears to be operable by soldiers in the transition MOS, and manning requirements can be met. This means that qualified operator personnel resources are available to initially field the system. Based on currently available manpower pools and recruiting practices there does not appear to be a significant burden in recruiting operator personnel necessary for sustainment of the personnel inventory.

Operator training requirements are consistent with current requirements for comparable air defense training programs and, in that regard, should not place an additional burden on the USAADASCH or unit training programs.

DISCUSSION AND RECOMMENDATIONS

Discussion

Establishing the viability of a system concept requires the resolution of specific operability and supportability issues. These issues have been addressed throughout this analysis to determine whether a soldier representative of the current personnel pool can operate a LOS-F-H surrogate system effectively, and whether the Army can afford the MPT burden. The response to these two concerns are conditional.

- A soldier representative of the current personnel pool can operate a hybrid system effectively if the equipment actually works as intended; if changes in the human/machine allocation scheme do not require a greater workload burden on the operator; and if HFE/SS/HH guidelines are met.

- The Army can afford the LOS-F-H operator MPT burden if (1) the system does not require additional manpower by a change in OWL requirements; (2) the qualifications requirements of the personnel are not increased, thus limiting personnel availability; and (3) changes to the system are not automatically reflected in a training solution requirement that increases the burden on the institution or the unit.

Once operability and supportability issues have been resolved initially, they must be monitored so as to stay in "balance" throughout the life cycle of the system or the assumptions underlying initial estimates might be negated. This does not suggest that changes cannot be made to the system, only that the "ripple" effect of such changes must be assessed.

To illustrate the potential impact of such changes, assume that a decision is made (e.g., to create an operator/maintainer MOS) requiring the LOS-F-H system operator to have an electronics aptitude area (EL) score of 100. Table 17 identifies the number of personnel available in MOS 16R with varying OF and EL scores. The number of personnel in MOS 16R that become ineligible for transition to operator training on the LOS-F-H is 53 percent of the current population versus 26 percent when only a prerequisite OF score of 100 is required (see Table 12). More significant impacts could also result from a decision to field the system with an operator/maintainer:

- Additional workload might drive up manpower requirements;
- Aptitude area prerequisites might affect the number of personnel eligible for training (noted above);
- Training might have to be lengthened; and
- Field training requirements might be raised (field commanders are currently required to train 10 percent of initial tasks, and train to sustain 100 percent of individual and collective tasks).

The illustrations discussed here may seem insignificant. However, several small or seemingly insignificant changes in the system can set up a synergistic "creeping burden" that will have a serious impact on the operability/supportability balance. Allowed to occur to any significant degree, the results of such an imbalance may result in the fielding of a system that can be neither operated nor supported effectively.

Recommendations

In conclusion, it is recommended that future MANPRINT evaluations of the LOS-F-H, as well as of the other FAAD components, include the assessment of the relationship between operability and supportability issues within the context of studies to be conducted. The analyses considered relevant are:

Table 17. EFFECT OF COMBINED "OF" AND"EL" SCORES
MOS 16R MAR 86 Enlisted Master File

SCORE	INELIGIBLES	PERCENT
OF 90, EL 90	554	22.77%
OF 91, EL 91	616	25.31%
OF 92, EL 92	689	28.31%
OF 93, EL 93	761	31.12%
OF 94, EL 94	820	33.70%
OF 95, EL 95	900	36.99%
OF 96, EL 96	989	40.64%
OF 97, EL 97	1,060	43.56%
OF 98, EL 98	1,147	47.14%
OF 99, EL 99	1,217	50.02%
OF 100, EL 100	1,302	53.51%

TOTAL = 2,433

NOTE: DOES NOT INCLUDE 619 INDIVIDUALS WITH NO "OF" SCORE RECORDED.

- In-depth operational suitability analyses, to include empirical timeline and related operator workload assessments;
- HFE/SS/HH and MPT assessments in a dynamic, tactical operational evaluation setting;
- An updated modified HARDMAN-type analysis (to more sufficiently address personnel and training issues);
- A Preliminary Training Effectiveness Analyses (PTEA).

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APPENDIX A

HUMAN FACTORS/SAFETY EVALUATION OF THE AIR DEFENSE LINE-OF-SIGHT FORWARD (HEAVY) SURROGATE SYSTEMS

I INTRODUCTION.

The Human Engineering Laboratory (HEL) conducted a limited human factors/safety evaluation of two surrogate air defense systems. A description of each system was previously presented. For the purpose of this report, the systems will be identified as Surrogate 1 and Surrogate 2.

A. Surrogate 1.

A two-day review of contractor material was conducted on 10-11 June 1986. This material included the Request For Information (RFI) contractor response, and information pertaining to safety, health hazards, and human factors engineering. Only minimal information on operator tasks was provided by the contractor. Following this information review, an assessment of a semi-operational system was conducted on 25 June. This system, which was provided for "hands-on" analyses, was housed on an M113 chassis. Since the U.S. Army is interested in this system integrated with the Bradley Fighting Vehicle (BFV), only a limited evaluation could be conducted.

B. Surrogate 2.

A two-day review of contractor material was conducted on 18 June 1986. This materiel included the RFI response and information pertaining to safety, health hazards, and human factors engineering. No operational system was provided for "hands-on" analyses. The contractor instead provided a turret shell on a stand for the evaluation.

II. REPORT CONTENTS.

The following information is supplied in this report:

A. Safety and Health Hazards Evaluation

B. Human Factors Evaluation

C. System Capabilities versus Proposed Threat

III. SAFETY AND HEALTH HAZARDS EVALUATION.

This evaluation was conducted through reviews of contractor documentation and a one-day observation of each surrogate.

The following topics will be presented:

- o Thermal Hazards
- o Electrical Hazards
- o Toxic Hazards
- o Laser Hazards
- o Noise
- o Radiation Hazards
- o Observations

The following safety and health hazards were found on the surrogate systems:

A. Thermal Hazards.

Surrogate 1. Extreme temperatures are produced by the Primary Power Unit (PPU). The contractor's system safety report lists the highest measurement at 538 degrees (all measurements are in Fahrenheit), taken at the PPU exhaust outlet.[1] Observations of the M113 vehicle showed this outlet on the side of the vehicle. It is not yet known where the outlet will be located on the BFV. This is a very serious hazard for anyone who is walking around the vehicle. The contractor's remedy to this hazard has been to use heat dissipating baffles to lower the exhaust temperatures. Efforts should be made to lower these temperatures further. Warning labels should also be placed near the outlet. The contractor's safety report also states that the PPU shuts down when the exhaust temperature reaches 1400 degrees (F).[2] Four missiles will be stowed in the two-missile compartments. Missile autoignition occurs at around 300 degrees.[3] Multiple engagements could produce that type of extreme temperature in the missile compartment, therefore a hazard may exist, depending upon the location of the PPU in the BFV.

Surrogate 2. No information on thermal hazards was found.

B. Electrical Hazards.

Surrogate 1. A 115 volt electrical hazard exists on the exposed surface of the germanium coated windows on the electro-optics (EO) module.[4] This voltage may be disabled at the EO operator's workstation and a warning label is located on the module. Other safety measures should be investigated to eliminate this hazard.

It is further recommended that the wiring above the EO operator's head be shielded from possible damage due to the limited head room inside the crew compartment.

Surrogate 2. No information on electrical hazards was found.

C. Toxic Hazards.

Surrogate 1. The contractor identified beryllium oxide and beryllium copper as the primary toxic materials used in the system.[5] Warning labels have been placed at the location, according to the safety report. The report also states that carbon monoxide, ammonia, lead and nitrous oxide levels are expected to be well below the limits specified by the Occupational Safety and Health Administration (OSHA) due to the supplemental ventilation system that circulates air at a rate of 1200 cubic feet per minute.

A toxic gas and fire hazard was linked to the vehicle batteries.[6] The contractor reports that hydrogen gas produced by the batteries is now vented to the outside.

It is recommended that toxic fume measurements be taken in the surrogate system integrated with the BFV to determine the levels produced by the integration.

Surrogate 2. The contractor's RFI response indicates that an insignificant level of carbon monoxide was measured at the gunner's position during testing;[7] however, contractor personnel indicated during the meetings that not only were high levels of carbon monoxide present, but also high levels of argon and freon. Hydrogen chloride (acid) gas is produced during missile launches. Additionally, extremely poisonous mercury thallium liquid may be released if the seeker dome on the missile is broken.

D. Laser Hazards.

Surrogate 1. This system has two laser subsystems; the Guide Beam Assembly (GBA) and the Laser Ranger (LR). The safe eye exposure distance (SEED) has been determined by the contractor. The SEED for the GBA is 70 meters and the SEED for the LR is 7,836 meters.[8] Eye protection must be worn by all personnel within these distances during lasing operations.

Surrogate 2. The contractor has reported that the missile guidance laser SEED is 140 meters[9] and the laser rangefinder SEED is 1100 meters.[10] Eye safety protection is required inside these distances. The radar and EO operators are protected from this hazard by protective glass surrounding their workstations.

E. Noise.

Surrogate 1. Impulse Noise - Figures in the contractor's RFI response show the missile peak impulse level to be 170 dBA at the exterior of the vehicle and 145 dBA at the interior of the vehicle.[11] It is likely that the dBA attached to the values are a misprint, since impulse measurements are not made using the A-weighted scale. The 170 dB is likely to be the actual impulse measurement since missile noise is normally at that range. Even so, the type of hearing protection required and the exposure limits cannot be determined without the B-duration that should accompany the blast overpressure measurement. Measurements for the gun were not available.

Steady-State - An 80 dBA contour was taken around the vehicle. The farthest recorded distance was approximately 19 meters at 270 degrees azimuth (primary noise source being the PPU).[12] Normally an 85 dBA contour is taken to determine at what distances personnel must wear hearing protection. It is therefore determined that 19 meters is farther than required, protection contour can be determined.

It is recommended that impulse noise measurements (with the B-duration) be taken on the missile and the gun in order to determine the safe exposure limits for personnel. Steady-state measurements should be made with the system integrated with a BFV. Those measurements should include:

1. 85 dBA contour
2. Interior measurements (stationary and dynamic)
3. Aural detectability measurements
4. Drive-by measurements

Surrogate 2. The contractor has reported that the gunfire impulse noise did not exceed 152 dB at the gunner's position when tested on the Light Armored Vehicle.[13] The contractor's safety assessment report states that double hearing protection has been required in the past to protect the gunner from noise.[14] It is not known what these measurements will be on the BFV. No measurements were taken during missile firings. The contractor has assumed that levels will be lower than those created by shoulder launched missiles.

Recommendations are the same as for Surrogate 1.

F. Radiation Hazards.

Surrogate 1. Radiation effects are negligible while the radar is rotating, however, a safe exposure distance of 35 feet is required when the system is radiating in the stationary mode for a period of 8 hours.[15]

Surrogate 2. The contractor claims the radiation from operations to be negligible. Personnel will be restricted from being on the vehicle during radar operation.[16]

G. Observations.

Surrogate 1. A hazard may exist at the driver's position while driving in the open-hatch mode. A missile positioned directly above the driver's head was observed to have an unsecured latch. Catastrophic results could occur if a 150-pound missile falls on the drivers head.

Since static electricity could cause a failure to occur in the missile subsystem, contractor testing includes pin-to-pin and pin-to-case testing with a capacitive discharge of 25,000 volts. Grounding of personnel and missiles is practiced during all stages of the assembly, disassembly, storage and testing operations.[17] It is recommended that grounding also take place during reload and resupply operations if those precautions do not already exist as standing operating procedures.

Fire suppression for the PPU and engine compartment is provided by a halon-filled fire extinguisher. The knob for this extinguisher is located in an awkward position behind the driver. No fire extinguisher was observed in the crew compartment. Fire extinguishers and controls for extinguishers should be located within reach of all personnel.

Surrogate 2. Personnel should be restricted from standing within 150 feet of the system during tactical firing. Launching creates an explosion of particles out the back end of the missiles.[18] Additionally, gun sabots fly from the system at high speeds during tactical firing. The contractor's safety report states that these sabots have severed instrumentation tables during testing.[19]

IV. HUMAN FACTORS EVALUATION.

A. Workspace. Workspace measurements were taken from drawings of the surrogate systems that were supplied by the contractors. The measurements provided were only for the tank commander (TC) and gunner positions. The workspace dimensions for Surrogate 1 interface directly with the interior of the BFV. Surrogate 2, however has a self-contained turret that requires almost no direct interface directly with the interior of the BFV. Surrogate 2, however has a self contained turret that requires almost no direct interface with the Bradley. The workspace dimensions at the TC and gunner positions on both systems and how they compare to the anthropometrics dimensions found in MIL-STD-1472C is presented in Table A-1.

Surrogate 1. These workspace measurements indicate limited headroom at the TC and gunner positions. The sitting height required for a 95th percentile male (minus his helmet is 38.2 inches. This system provides a sitting height of approximately 34.0 inches, however, the contractor claims that a hatch will be located above the TC position that will supply 8 additional inches of overhead space. The RFI reports that the

Table A-1

Workspace Dimension (Inches)

Description	1472C Requirement (95th Percentile Male)	Surrogate 1		Surrogate 2	
		Measure	Percentile	Measure	Precentile
Sitting Height, erect	38.2	34.0[1]/38.6[2]	15/>95	48.0	>95
Sitting Height, relaxed	37.3	34.0[1]/38.6[2]	15/>95	48.0	>95
Elbow Grip Length	15.1	15.1	95	*	*
Elbow Rest Height	11.0	9.5	50	*	*
Popliteal Length	19.7	15.0	<5	20.2	<95
Buttock - Popliteal Length	21.5	22.3	<95	13.5	<5
Ceiling Height	73.1	48.5	<5	61.0	<5
Shoulder Breadth	19.6	*	*	18.8	80
Hip Breadth, sitting	15.1	*	*	16.0	<95
Hatch Diameter	28.0 arctic	*	*	23.0	NA

* Measurement could not be determined from drawing
1 Measured from seat reference point to ceiling.
2 Measured from seat resting on the floor to ceiling.

system is transportable, survivable, and maintainable by personnel wearing arctic or nuclear/biological/chemical (NBC clothing. Seated workspace widths could not be determined from the drawings, however it is determined that problems may arise when two large soldiers are wearing arctic clothing.

The seating in this vehicle is sideways, with the two crewmen facing the right rear wall. The ability of the crewmen to travel cross-country sideways without suffering any ill effects (motion sickness, unusual fatigue, etc.) should be addressed.

The seats provided have armrests, however, comments made by the contractor representative has indicated a need for an extension to the right armrests that will provide adequate wrist support when using the handgrips. Contractor testing apparently showed that the operator's wrist/arm becomes fatigued due to the slant between the armrest and the grips. An extension could be a remedy for this problem, although the impact on emergency evacuation should be determined before modifications are made.

Elevating the seat requires a two lever adjustment. Both levers are positioned on the same side and cannot be operated while the crewman is seated. It is recommended that the seats be supplied with a spring-loaded mechanism that allows the operator to adjust the seating height in a quick and efficient manner.

Surrogate 2. The workspace measurements provide by contractor drawings indicate that there may be limited workspace surrounding each crew position. The required shoulder breadth for a 95th percentile male is 19.6 inches. The amount of space provided by the system is 18.8 inches. This workspace problem will be compounded when wearing nuclear/biological/chemical (NBC) or arctic clothing. After observing the actual turret configuration at the contractor facility, however, it appears that there may be adequate shoulder room due to a cut-out that is being provided between the two crew members. On contractor representative indicated that there was more workspace in the turret that originally expected.

A metal rim is located behind the head positions in the turret. This could cause head or neck injury if an operator is thrown against it during operations. It is recommended that padding be installed to protect the operator.

Ingress and egress are expected to be problems for both systems in addition to the workspace constraints at the crewstations. It is recommended that complete workspace measurements be taken on each system to determine if they can meet the needs of 5th through 95th percentile users.

B. Visibility. Although no objective visibility measurements could be taken on the systems, the following observations were made:

Surrogate 1. Visibility is provided by the following:

1. Driver's vision blocks

2. TC's vision blocks

3. Electro-optics (EO)

It is expected that the EO will be needed to meet the majority of visibility needs. Since positive visual identification must be made before target engagement, it is recommended that a study be conducted to determine the ability of th system to meet that need.

Surrogate 2. Visibility is provided by windows as well as the EO. These windows provide 35 degrees of vertical view and 180 degrees of horizontal view. The 180 degrees is angled from about the 10-4 o'clock position if seated at the right side of the turret and from about the 8-2 'o'clock position if seated at the left side of the turret. This view is partially obstructed by cornerposts.

C. Gun System. The gun is reloaded inside the turret by the gunner and TC.[23] No detailed procedures were provided for this task and no problems concerning loading from a resupply vehicle could be determined from this evaluation.

D. Controls and Displays.

1. Radar Operator Control Panel.

Surrogate 1. The RFI response states that this system can interface with the Forward Area Air Defense Command, Control and Intelligence (FAAD C^2I) system currently in development.[24] The symbology of DOD-STD-1477 must be incorporated as well as other C^2I concepts. A detailed investigation must be made to determine the stowage of additional required equipment as well as the full integration of the C^2I concepts.

Although having different displays and different functions, the radar and EO workstations have the same type of handgrip. The handgrip at the radar operator's workstation is used for tracking and hooking a target for hand-off to the gunner. This is accomplished by using a thumb switch and trigger. The handgrip at the EO operator's workstation is used for tracking the target and firing the missile or gun. The switches used for this task are identical to the type used by the radar operator to perform his tasks. Since all crewmembers must be cross-trained on this system and one man may be required to

Table A-2

Reloading Time-Lines (Approximations) Values are in Minutes

	Surrogate 1 w/Semi-automatic Loading Mechanism		Surrogate 2	
Description of Task	3 Men	5 Men	2 Men	4 Men
Stow to ready to fire:				
Gun	7.0 (240 rds)		15.0[a] (450 ready; 1050 stowed)	
Missile - type 1[b]	7.3 (4 ready)		NA	
type 2A[c]	NA		3.0 (2 ready; 4 stowed)	
type 2B[c]	NA		4.0 (4 ready; 4 stowed)	
Supply vehicle to ready to fire:				
Gun		6.3 (240 rds)		10.0 (450 ready; 1050 stowed)
Missile - type 1		10.1 (8 ready)		
type 2A				2.0 (2 ready; 4 stowed)
type 2B				3.0 (4 ready; 4 stowed)
Supply vehicle to stow:				
Gun		14.0 (540 rds)		5.0 (450 ready; 1050 stowed)
Missile - type 1		5.0 (4 stowed)		
type 2A				3.0 (2 ready; 4 stowed)
type 2B				2.0 (4 ready; 4 stowed)

[a] Time can be decreased by topping off" the storage unit between engagements.
[b] Missile used by Surrogate 1.
[c] Missiles used by Surrogate 2.

operate both the radar and EO consoles, this similarity of operation may prove to be a problem. An investigation should be made into the effects of cross-training and how well one crewman can perform both tasks of EO and radar operator while under stressful battlefield conditions.

Although the radar display provides the air picture to the TC, ground targets are not displayed unless they are moving faster than 25 meters per second (55 mph). The limited visibility provided by this system will probably degrade the ability to detect slow moving stationary ground targets. The EO operator will use his display to search and scan for ground targets. During march order, the EO module will be locked down allowing only limited field of view. The radar operator is not provided any ground target information form his display, so he must make a visual scan through his vision blocks. The location for the TC's hatch has not yet been determined. If it is positioned at his workstation, he will be able to raise his seat(it should be spring-loaded as previously mentioned) and make a visual search and scan through his vision blocks. If, however, the hatch is positioned behind the driver, the TC will be able to direct the driver in his task, but he will have to change seating positions to do so. This position will also limit his ability to see the area behind the vehicle. The tasks required by the TC must be studied to determine how they will interface with this air defense system.

Some of the control groups should have labels identifying them. These include the function keypad, and the radar status indicators. All controls/indicators that have covers should be labeled on the exterior of the cover in accordance with section 5.5 of MIL-STD-1472C.

Surrogate 2. The RFI responses states that this system has the capability of interfacing with the FAAD C^2I system.[25] Contractor information further states that the system is compatible with EPLRS data format. Due to the lack of information provided by the contractor, any difficulties experienced by operators could not be determined during this evaluation. Although the radar primarily displays the air picture to the operator, it can also present moving ground targets. The radar has two selectable filters that can detect targets moving as slowly as 5 meters per second (12 mph).

2. EO Operator Control Panel

Surrogate 1. The function keypad is used to enter numerical codes into the software. A manual describing these codes is used during operations. It is assumed that operators will learn the codes during training and will then automatically know which codes to use and when. This should be further investigated to determine if there may be a need for menuing these functions instead of providing a manual. If a manual is used, it is recommended that storage space be supplied for it in a drawer under the operator's control panel. This manual must be readily accessible to the operator at all times.

The labels above the FLIR controls are obstructed by the control and therefore should be relocated. The requirement for the location of labels is found in section 5.5.2.2 of MIL-STD-1472C. Labeling is needed for all grouped controls.

In addition to the EO control panel, the operator must have access to the primary power unit (PPU) controls and displays. During the demonstration on the M113, the PPU was located next to the operator and facing the back of the vehicle. In this configuration, it was difficult to operator the main circuit breaker and brake release switches that were located on the right side of the PPU. Both switches required blind operation. Contractor personnel, however, indicated that the panel is likely to be located behind the EO operator in the BFV. This creates further human factors problems due to the inability of the operator to easily access the switches as well as the total lack of ability to monitor the indicator lights without making a conscious effort to turn to look at them. Requirements for location of displays is found in section 5.2.1.4 of MIL-STD-1472C.

The heater controls are accessible to th EO operator only when he lowers the back of his seat. He can then operate the control in the reclined position. Additionally, the engine grill open/closed indicator light is located near the turret at the roofline. The indicator light should be located within the line-of-sight of the operator since failure to open the grill before traveling could result in the engine overheating. The grill is closed during missile firings to prevent toxic fumes from entering into the crew compartment.

Surrogate 2. The gunner's engagement task requires a seven-step operational sequence between two handgrips and one foot control. This sequence does not seem to follow a logical, easy to remember pattern. It is therefore recommended that this method be studied to determine its effectiveness and trainability.

E. Speech Intelligibility.

Surrogates 1 and 2. A determination of the interior steady-state noise levels created by the candidate systems integrated with the BFV could not be determined by this evaluation. Intelligibility scores of at least 75% for Phonetically Balanced or 91% for Modified Rhyme tests should be expected from the system communications. This provides normally acceptable intelligibility; about 98% of sentences correctly heard. This requirement is found in Table 6 of MIL-STD-1472C.

V. SYSTEM CAPABILITIES VERSUS PROPOSED THREAT

A simple, unclassified threat analysis was conducted on the two systems to determine each system's ability to meet the low-altitude air threat of the mid 1990's and beyond. This analysis defines each system's ability to detect, engage, and destroy both moving and stationary rotary and fixed-wing targets. All information presented was supplied by contractor material.

A. Missile Systems

The characteristics of each system are as follows:

1. Surrogate 1 uses a laser, beam-riding missile.

2. Surrogate 2 uses two different systems, an infrared heat-seeking, fire-and-forget missile and a laser beam-riding missile. For the purpose of this analysis, the missiles for the Surrogate 2 system will be identified as Missile I and Missile II.

B. Gun Systems

Both contractors use a 25-mm hybrid gun system. These gun systems are to be used against ground targets and for coverage of missile system dead zones (the dead zone is that area between the weapon system and that missile system's inner launch boundaries).

Each system's maximum range, launch and intercept boundaries, intercept reaction times, and the probability of a kill (PKa) are presented in Table A-3.

The contractor information gives the appearance that the Surrogate 1 system is better capable of meeting the low-altitude air threat of 1995 and beyond. The missile system has greater range and faster reaction time. Even though the Surrogate 2 system can shoot on-the-move, its reaction time from target detection to missile intercept is much longer. Both 25-mm guns have comparable ranges and kill probabilities.

Table A-3

System Capabilities Versus Threat Comparison

	Surrogate 1	Surrogate 2 Missile I	Surrogate 2 Missile II
Missile:			
1. Maximum Range	10 + km	6 km	6 km
2. Boundaries for Targets Traveling 1-250 m/s[a]			
a. Launch	10 + km	6 km	6 km
B. Intercept	8 km	4 km	6 km
3. Launch/Intercept Reaction Times for Incoming Target Traveling 1-250 m/s at 6 km:			
a. Launch[b]	8.0 sec	6.5 sec	6.5 sec
b. Intercept[b]	17.0 sec	40.0 sec	40.0 sec
c. Launch[c]	13.0 sec	6.5 sec	6.5 sec
d. Intercept[c]	22.0 sec	40.0 sec	40.0 sec
4. Pka:			
a. Launch at 6 km Target	.9	.6	No data
b. Launch at 8 km Target	.9	No data	No data
Gun:			
1. Maximum Range	2 km	2 km	
2. Pka Against 2km Ground Target	No data	.3	
3. Pka Against 1.5 km Air Target	No data	.2	

[a]Surrogate 1 is capable of engaging targets traveling faster than 250 m/s.

[b]Measured w/system emplaced and in ready-to-fire mode. Times are from target detection to missile launch/intercept.

[c]Measured from target detection to missile launch/ intercept from the move (Surrogate 1 cannot shoot on the move.)

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11. Surrogate 1. (1986). Contractor RFI (unclassified). Orlando, FL. p. I-14.

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17. Surrogate 1. (1985). Contractor Safety Hazard Matrix (Document ANA00500000-002). Orlando, FL. p. 9.

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24. Surrogate 1. (1986). <u>Contractor RFI</u> (unclassified). Orlando, FL. p. I-83.

25. Surrogate 2. (1986). <u>Contractor RFI</u> (unclassified). Burlington, VT. p. GS-29.